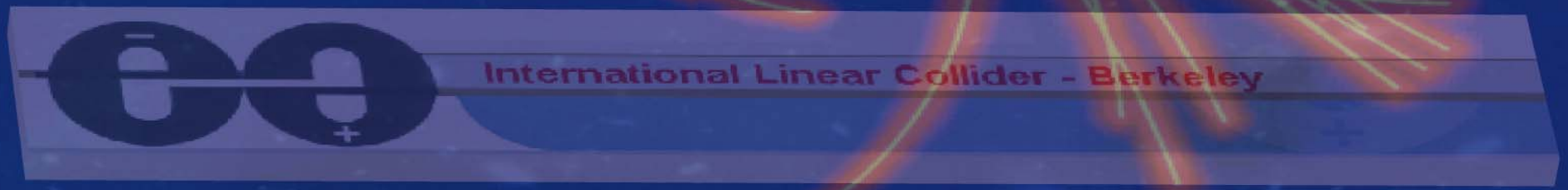
The ILC Project at LBNL

Marco Battaglia
UC Berkeley and LBNL



LBNL Director's Review
November 10, 2004

Particle Physics and Cosmology

have reached their Standard Models
now both face new fundamental questions:

What's the origin of Mass ?
What's the nature of New Physics ?
What's the path to Unification ?

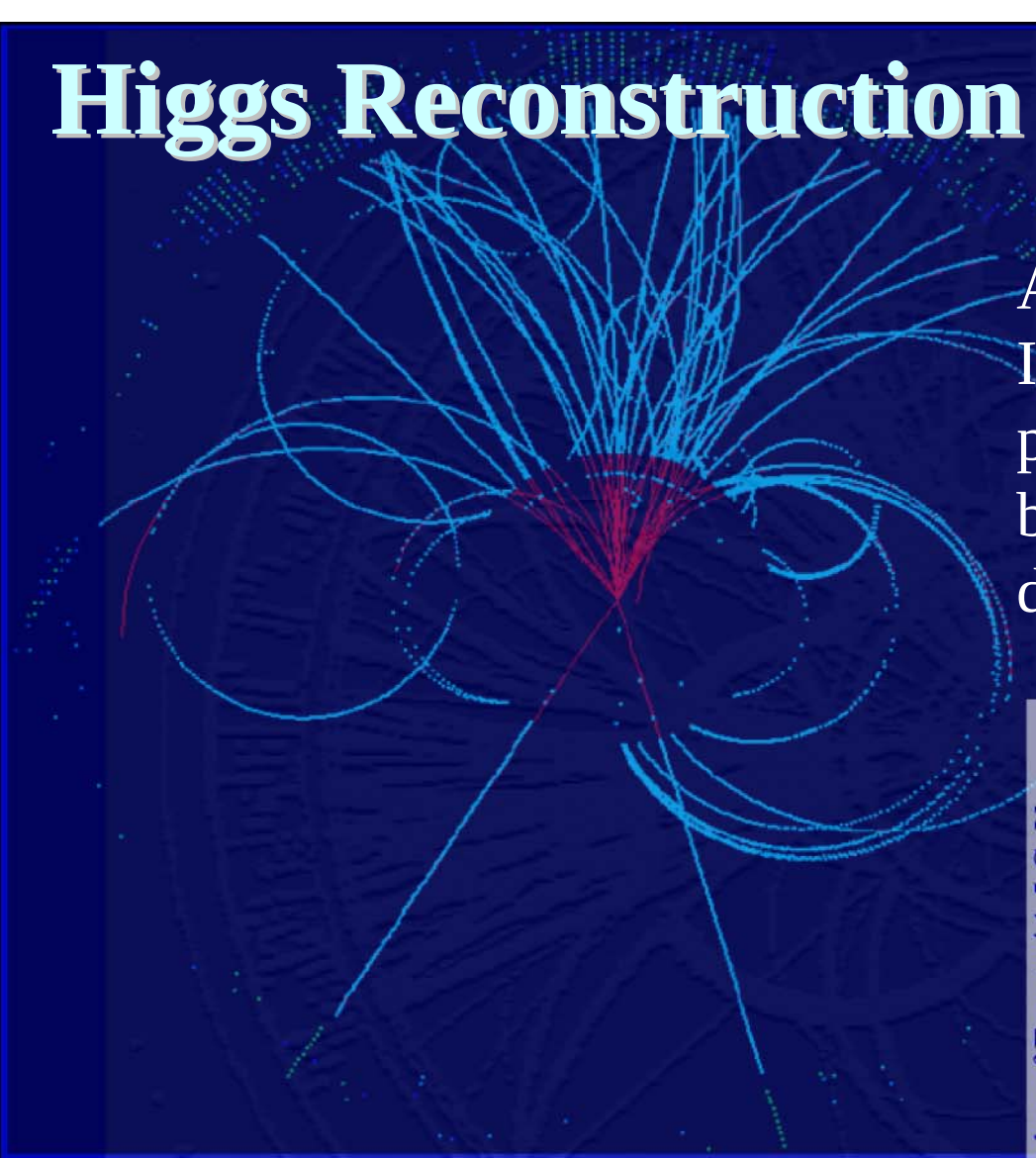
What's the nature of Dark Matter ?
What's Dark Energy ?
What's the nature of Inflation ?

Particle Physics entering new era where decisive experiments will yield deeper understanding of fundamental questions regarding the basic building blocks of matter, their interactions and their relation to Cosmology.

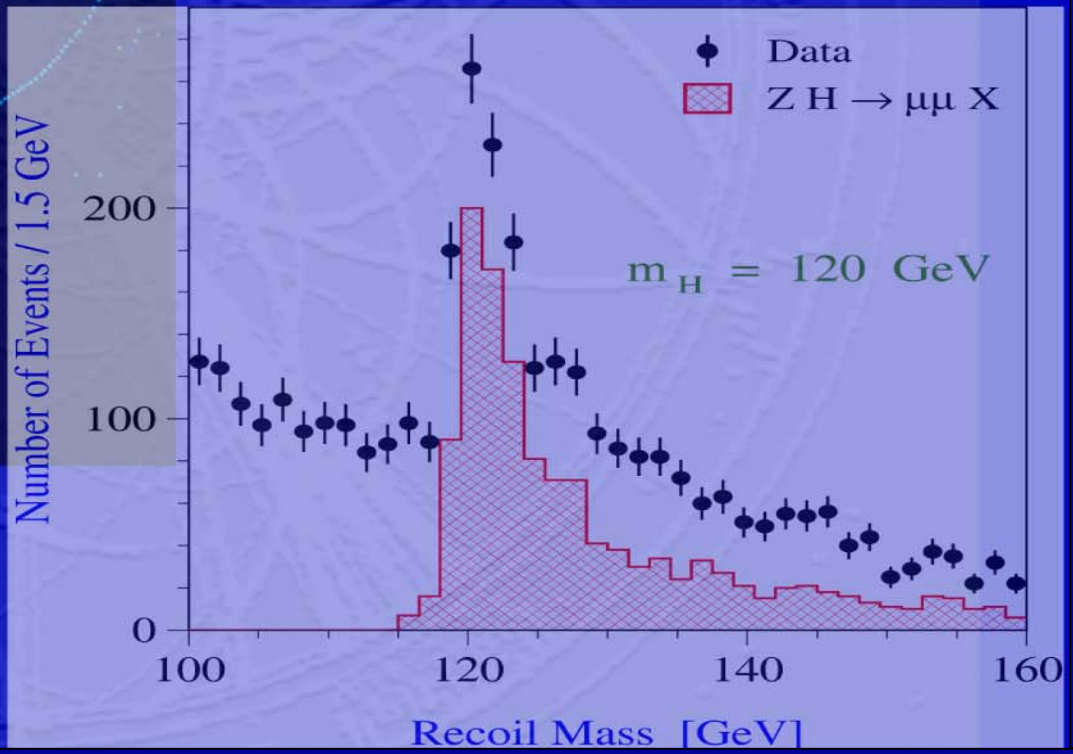
LHC to provide next step in exploration of higher energy scales; Higgs boson observation will exhaust search for new particles predicted by Standard Model. However, there are very compelling reasons to believe that Standard Model is not the final theory and New Physics exists beyond it.

Precision data at $\mathbf{e^+e^-}$ **International Linear Collider** needed to extend and complement discoveries with accuracy which is crucial to test fundamental properties of new phenomena.

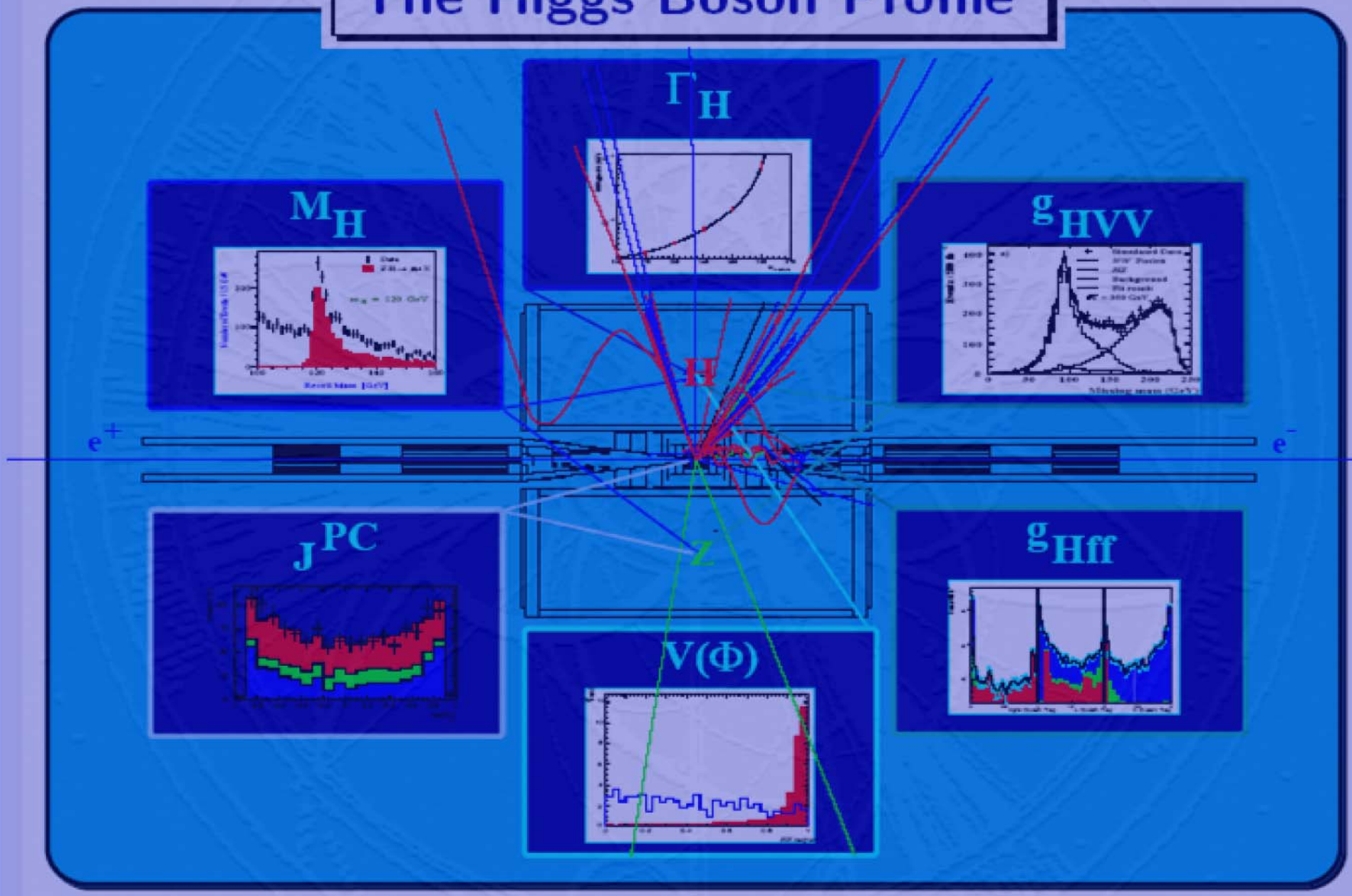
Higgs Reconstruction at the ILC



Associated $e^+e^- \rightarrow ZH$ production makes ILC an **ideal laboratory to study Higgs** properties in details: Higgs signal would be revealed even if none of the Higgs decay products were observable

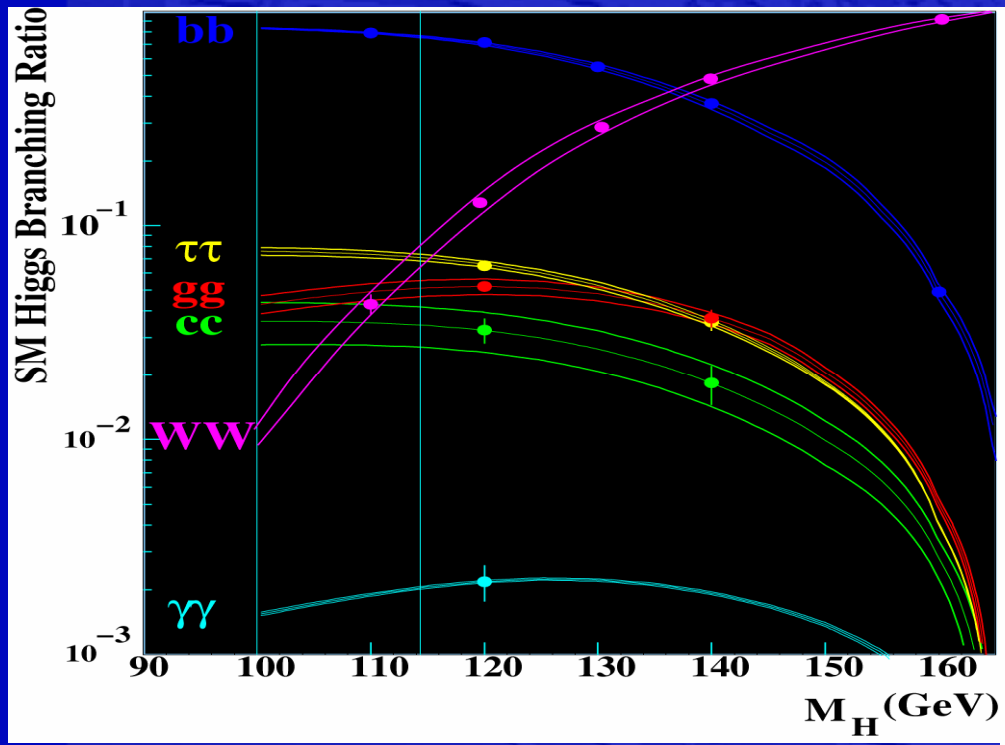


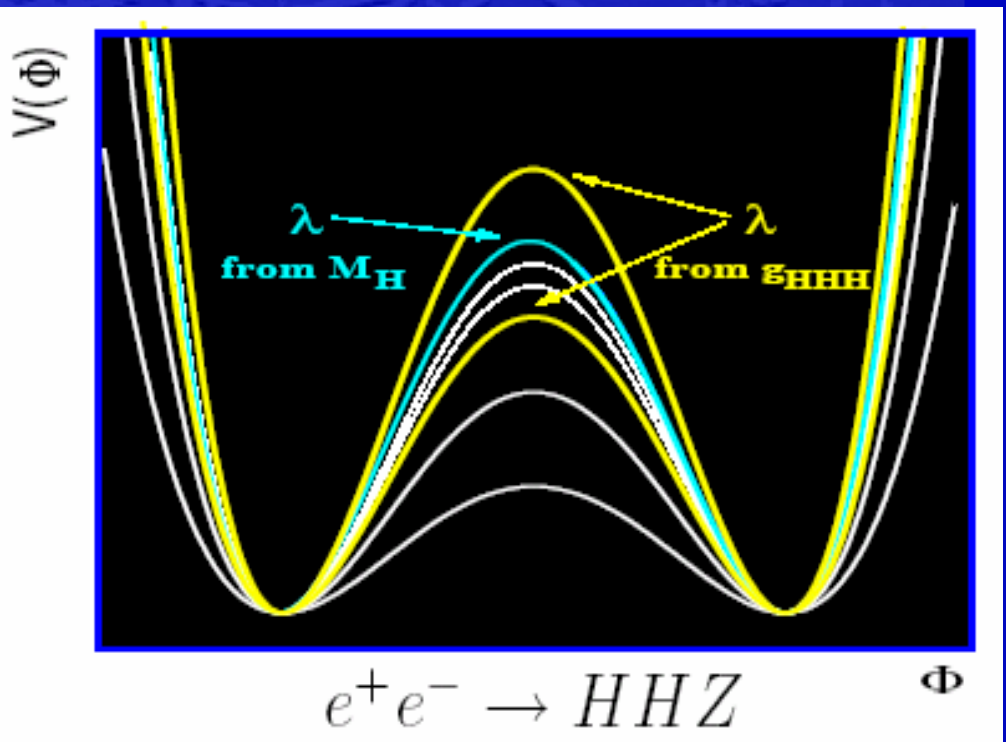
The Higgs Boson Profile



Strengths of **Higgs couplings** to **force and matter particles** can be determined accurately from study of Higgs decays.
At ILC possible to perform **fundamental test** of proportionality between **masses and couplings** strength.

Interactions of Higgs bosons with each other known once mass is defined. These too can be measured at the linear collider. These measurements will **definitively establish that Higgs mechanism** provides both **force and matter particles** with their **masses**.

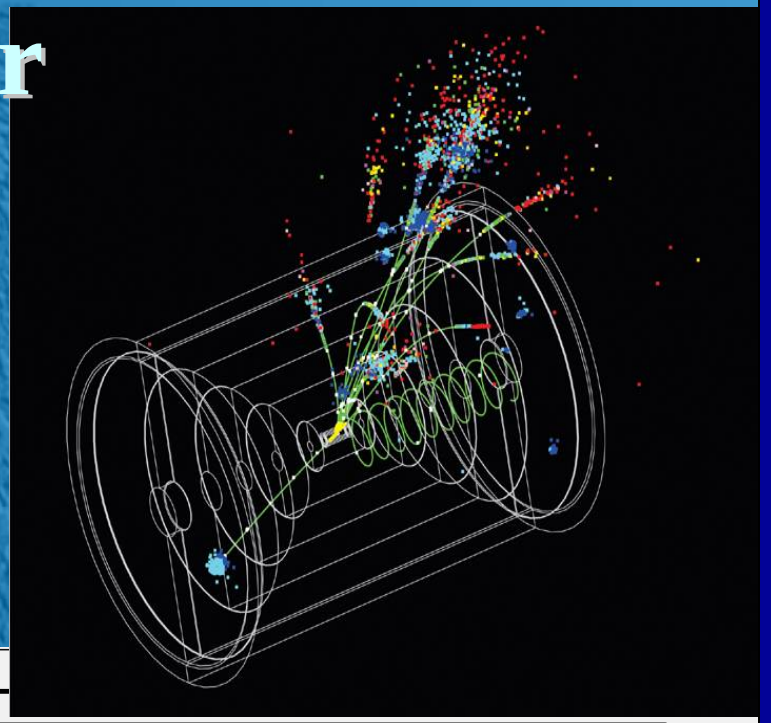


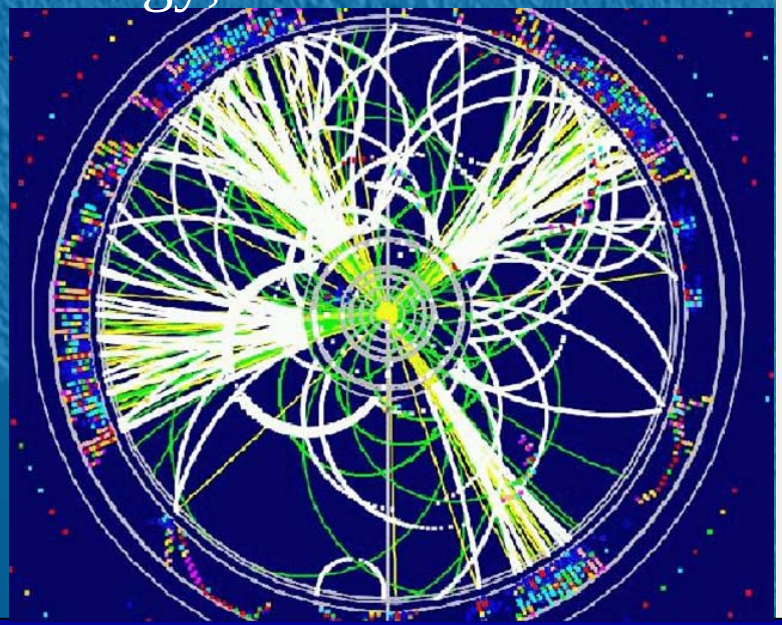


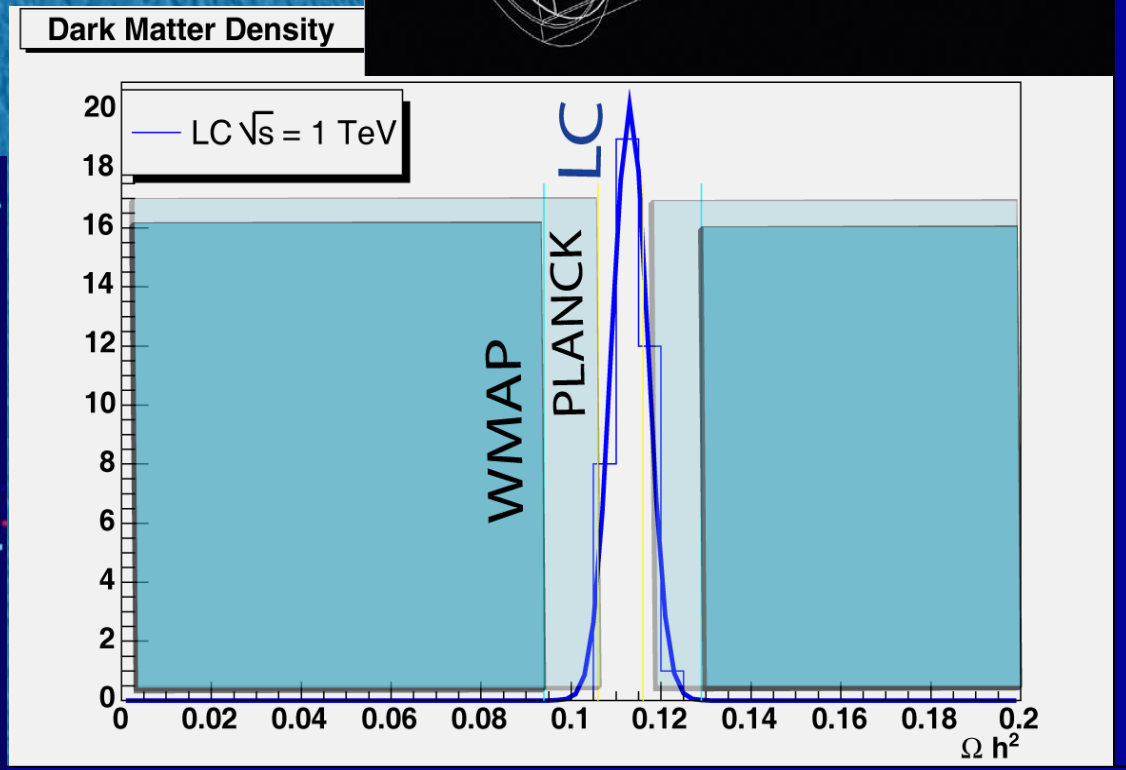
ILC Physics and Dark Matter

Collider experiments to provide complementary information, comparable accuracy to satellites on **Dark Matter** by **directly producing** the particle responsible, establishing its nature and studying its properties under controlled conditions;

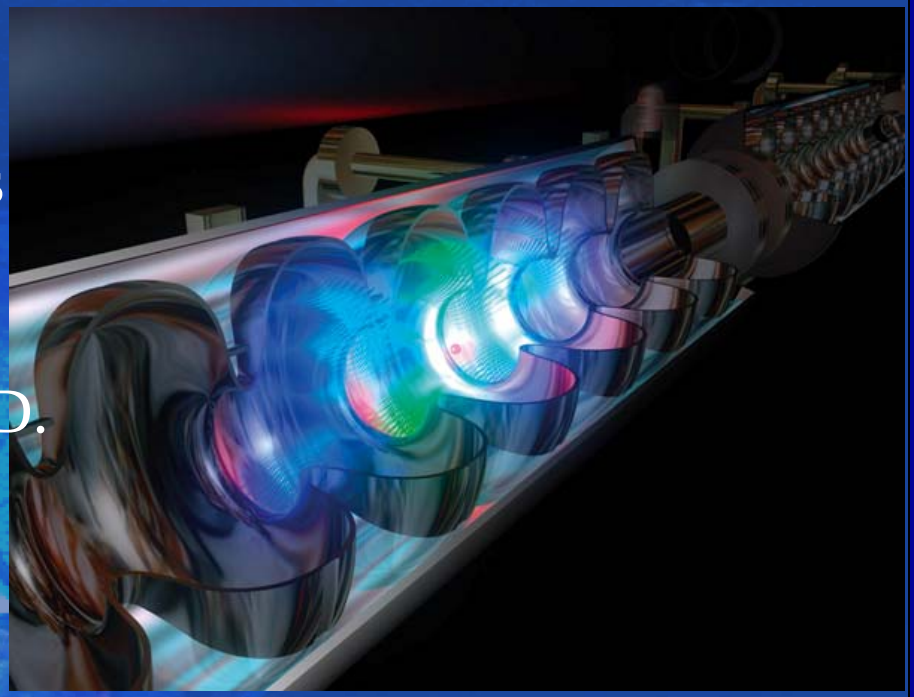
If results will agree it will be great triumph for both Particle Physics and Cosmology;







ILC essential part of program to gather new insigths into the structure of **Space, Time, Matter and Energy**. Given its cost and complexity, ILC will have to be realized as a **world-wide project:**



Accelerator R&D reached maturity to assess technical feasibility and informed choice of most advantageous technology. ILC potential in future of scientific research praised by OECD. DOE Office of Science ranked ILC as **top mid-term project**.

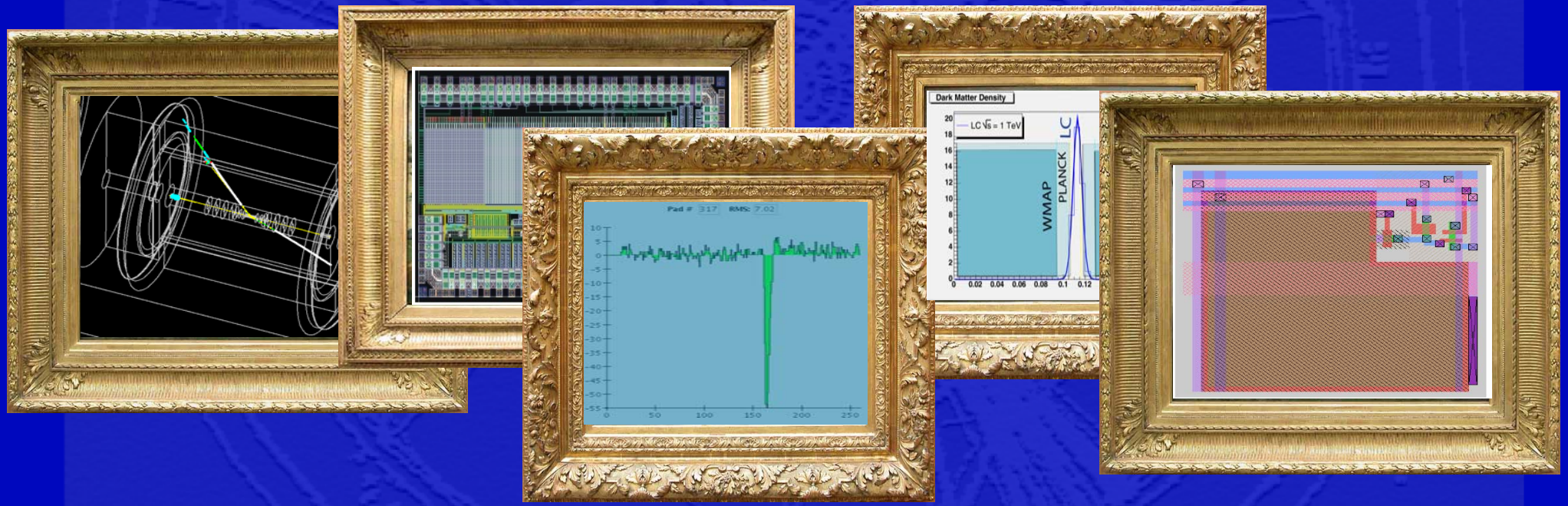
Major step towards construction of new HEP facility in August 04:

ICFA endorsed recommendation on **SC cavities** as technology for Linacs **Global Design Initiative** to produce costed Technical Proposal by 2006: LBNL offered to host GDI.

ILC establishes new directions for detector R&D: **thinner** and **more precise** sensors, high **channel density**, **rad-hard**, low **power**: to meet physics requirements needs innovative technologies, as well as new detector concepts.

Physics Division ILC project establised in October 04
to carry out Physics Studies, Detector Design and R&D

Divisional LDRD program started in October 04
to develop Monolithic Si Pixel Sensors

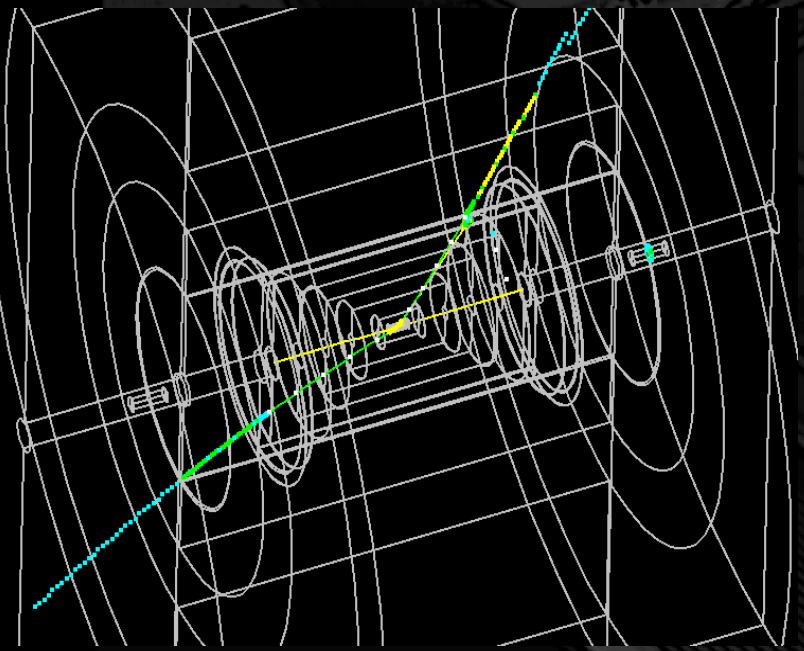


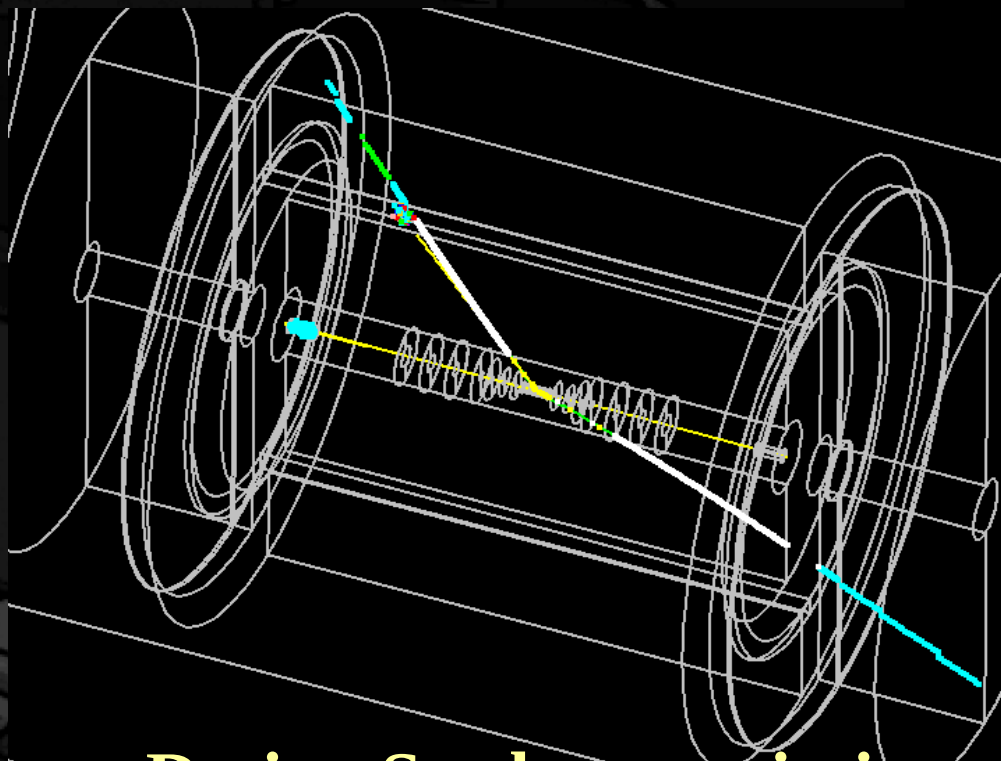
Collaboration with AFRD, concentrating on damping rings, on machine interface issues and program coordination.

ILC Detector Design Study

Main Tracker technology drives LC detector design:

- **Large Detector** based on 3D **TPC** Main Tracker
- **Compact Detector** based on **all-Si** Main Tracker

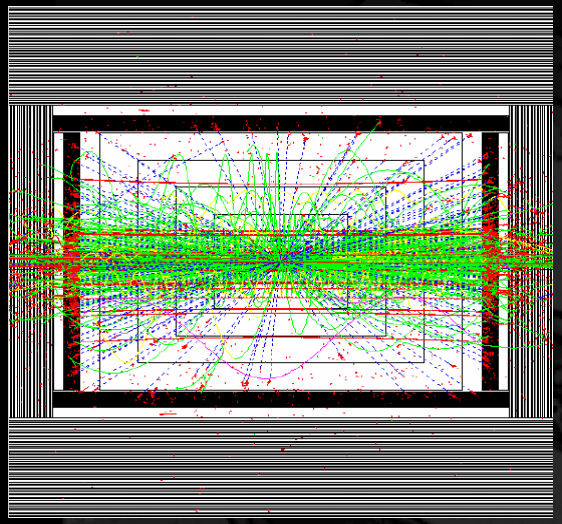


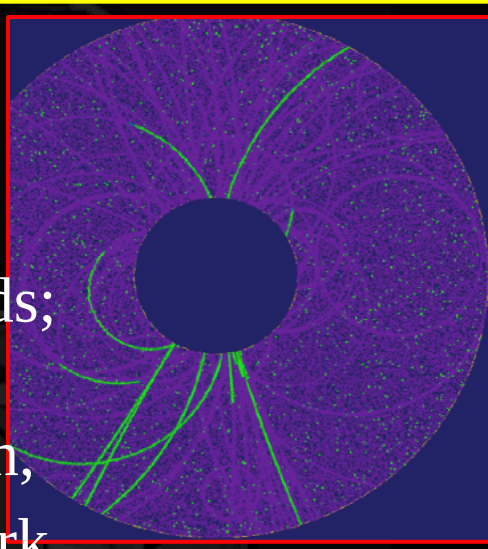


Detector Design Study to optimise,
and **physics benchmark**
fully integrated **Detector concepts**

Design activity to bridge from **physics** studies to **R&D** assessment
LBNL leadership in US Large Detector Study

ILC Detector Simulation and Reconstruction

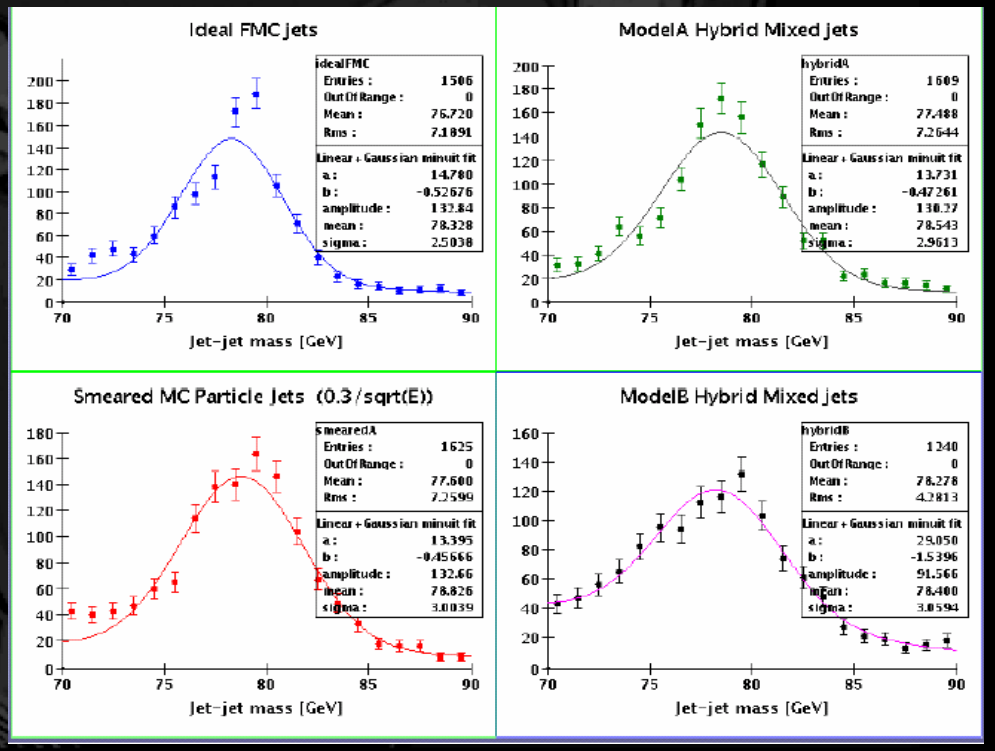




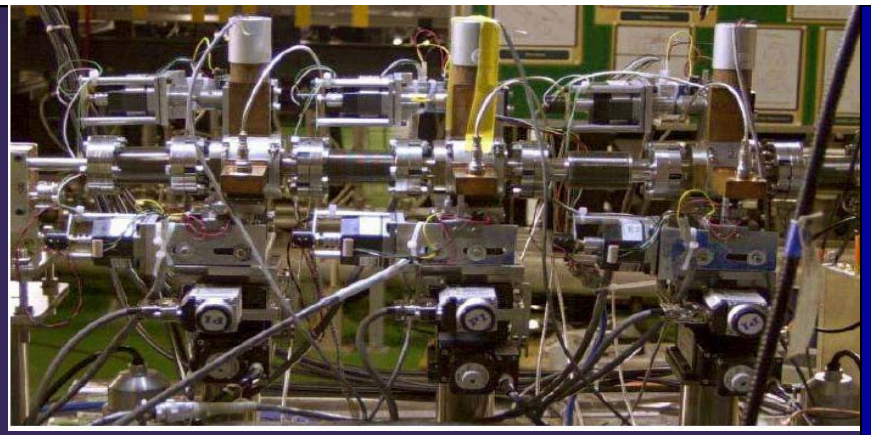
Detector Design supported by detailed simulation and reconstruction studies including machine induced backgrounds; LBNL active in definition of physics benchmarks, Vertex Tracker simulation, TPC patrec and Java analysis framework

Hybrid MC, combining reconstructed particles with true MC information, allows detailed studies of individual detector components

NERSC support for computing-intensive physics and detector simulation and code and data repository



NanoBPM Project and Beam Energy Spectrometer



ILC needs single pulse beam position monitor to O(10 nm) accuracy:

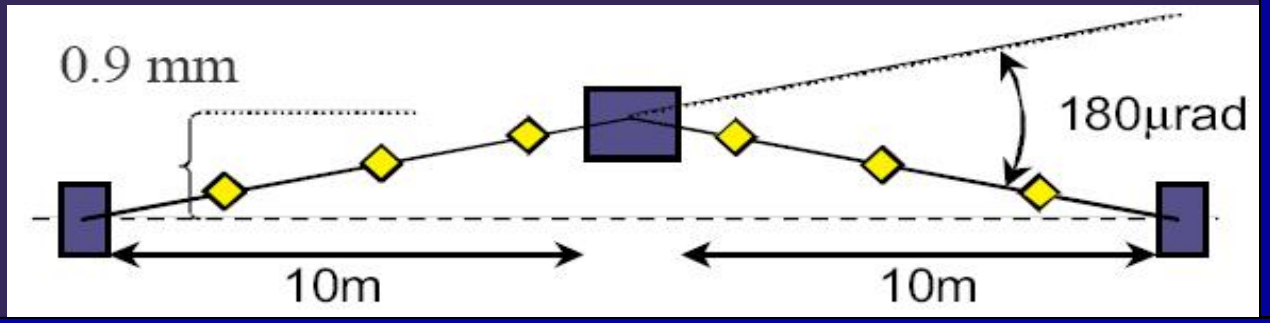
- position resolution and accuracy for **IP beam feedback**;
- beam tilt measurement for **luminosity preservation**.

Collaborative effort with SLAC, KEK, LLNL and London
UC Berkeley contribution funded through NSF LCRD grant

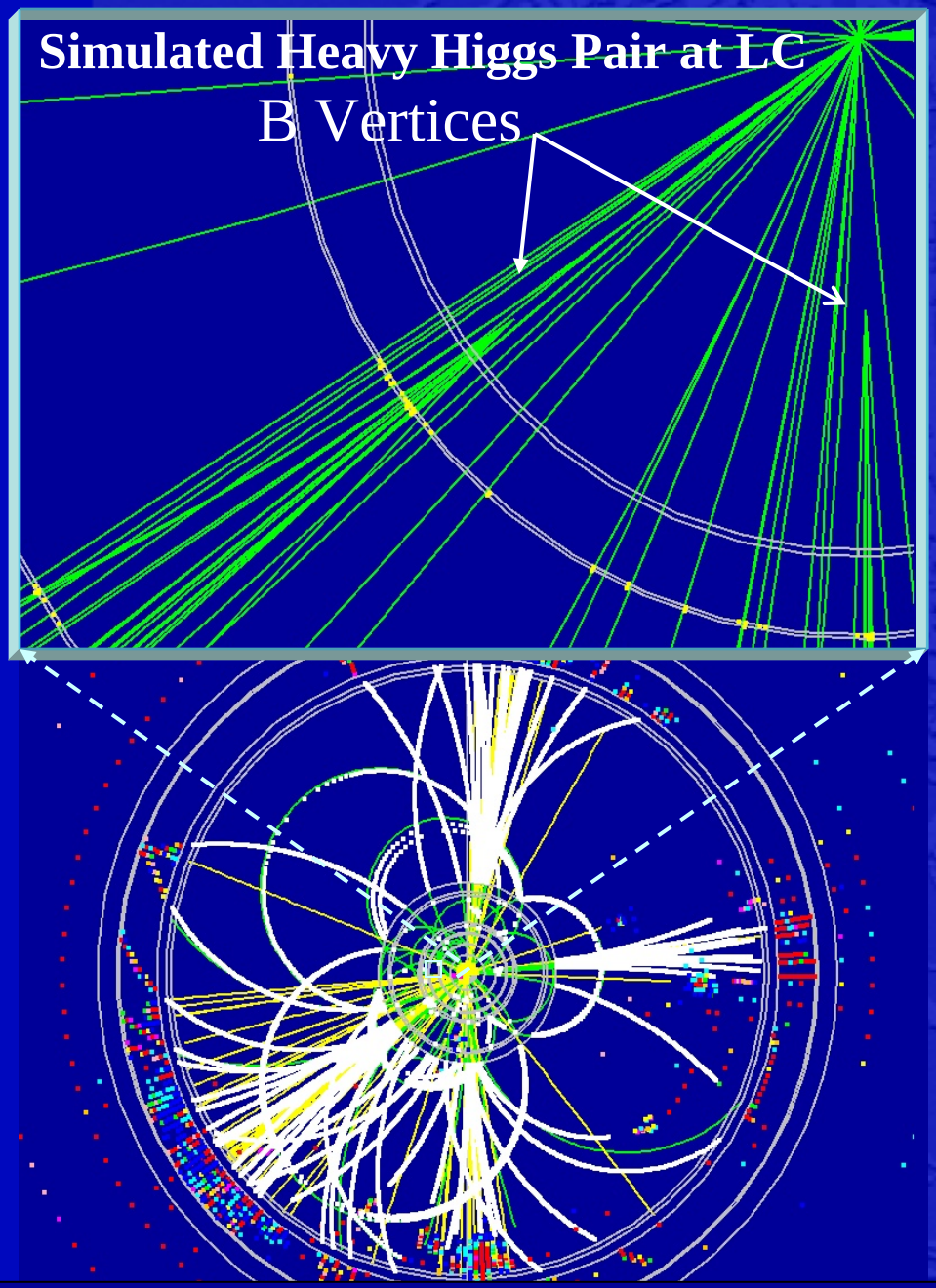
Beam test at KEK have demonstrated 70 nm resolution;

ILC Physics program requires **beam energy** to be known to better than 10^{-4} (factor 3 better than achieved at LEP): design of spectrometer based on BPMs upstream of IP: to be tested at SLAC End Station A in 2005 and 2006

Beam Energy Spectrometer Collaboration (UCB, SLAC, Notre Dame, London)



Comparison of Tracking Performance Targets



Extrapolation to Collision Point

$\sigma_{ip} = a \oplus b / p_t$	a (μm)	b (μm GeV)
LEP	25	70
SLD	8	33
LHC	12	70
RHIC II	**14**	**12**
LC	**5**	**8**

Momentum

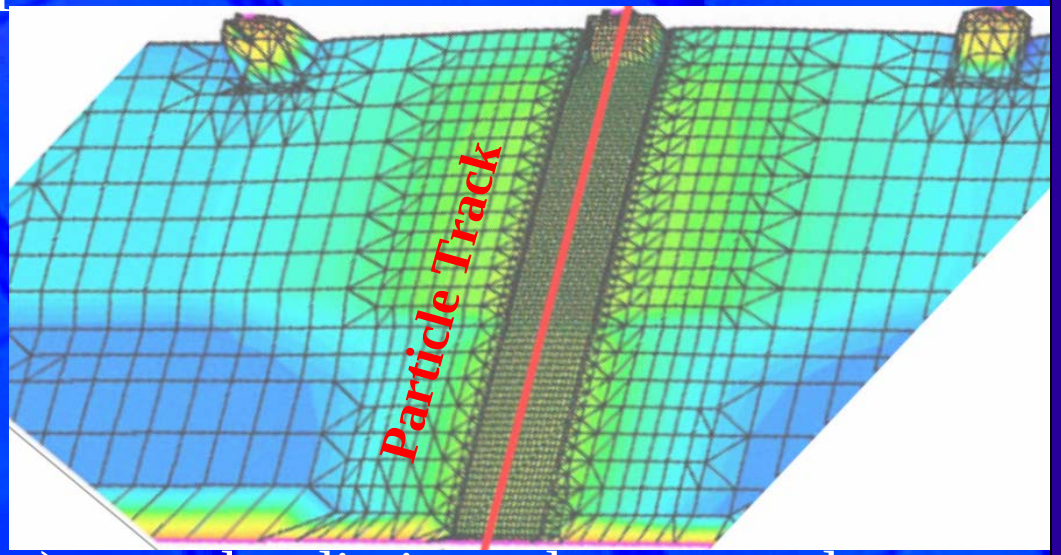
$\delta p / p^2 GeV^{-1}$	TPC Only	All Tracker
LEP	$1.2\ 10^{-3}$	$5\ 10^{-4}$
LHC	--	$2\ 10^{-4}$
LC	**$1.5\ 10^{-4}$**	**$6\ 10^{-5}$**

Novel Monolithic CMOS Pixel sensors

from Digital Cameras to Accelerator Experiments:

Combine signal process on detector chip: pioneering experience at IReS, LBNL NSD provided proof of concept:

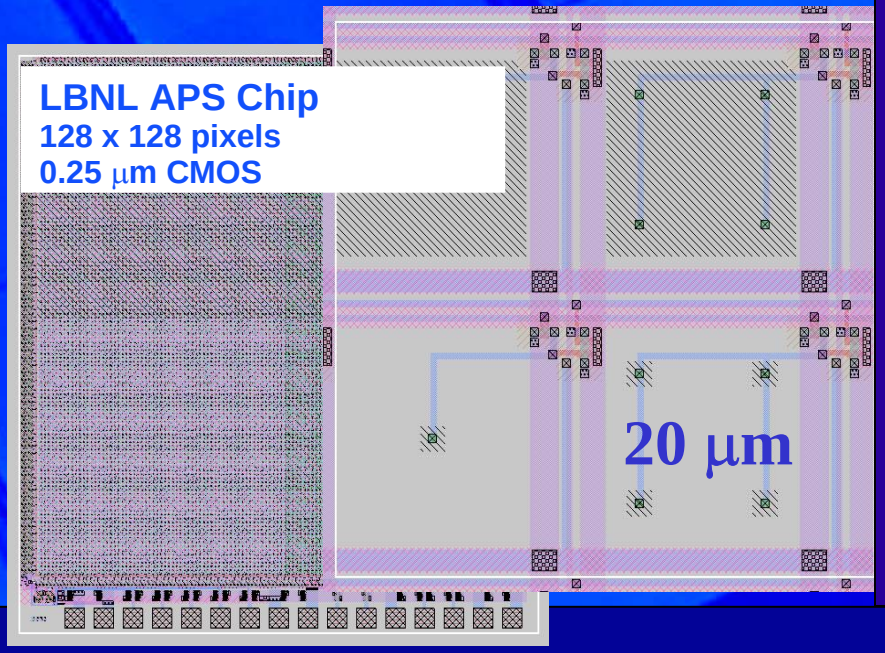
Fabrication process: industry standard, cost effective, easily available



Excellent single point resolution O(1 μm), good radiation tolerance and **minimal thickness** O(50 μm)

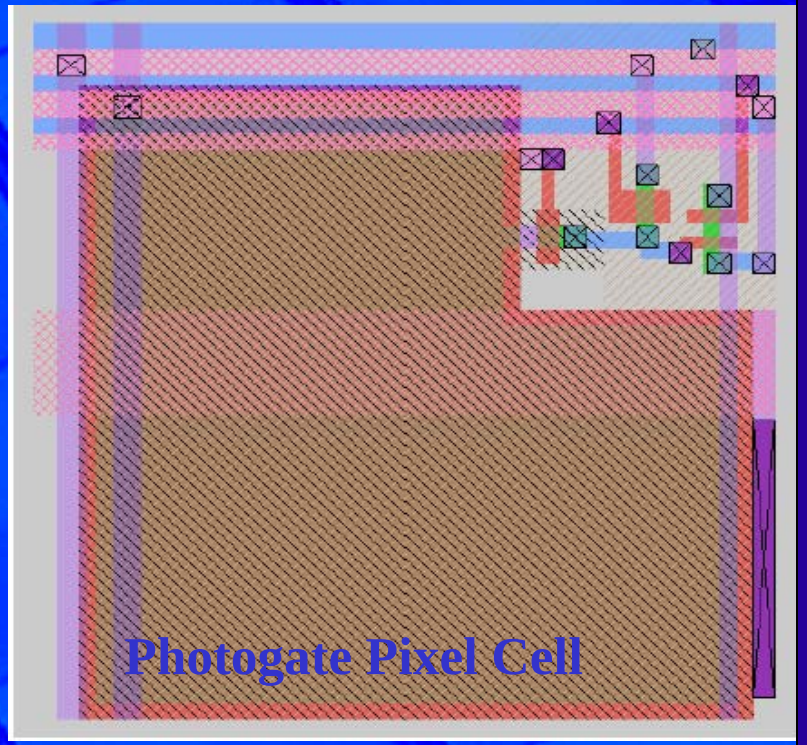
Now need to develop into **smart sensors** with **fast read-out** capability and **data reduction** implemented **on chip**:

Important interplay with applications beyond boundaries of particle physics (medical imaging, electron microscopy, astronomy, ...) :
collaboration with Engineering Division (LDRD)



LDRD on CMOS Pixel Sensors

Pursue R&D to achieve improved charge collection capability, noise suppression, fast read-out and data sparsification:



Evaluate PhotoGate design:
- improved signal collection
- rapid refresh to avod pile-up
- on-chip correlated double sampling for noise suppression

Implement **active reset functionality**:
- reduce kTC noise
- reduce fixed pattern noise

Evaluate **CMOS imager technology**:
- thick epi-layer
- reduced leakage current

Plan for FY05:

Characterisation of CMOS test structures with different pixel size;
Design and submission of test chip with active reset;
System design for integration of functionalities on pixel chip;
Develop specialised circuit for baseline subtraction.

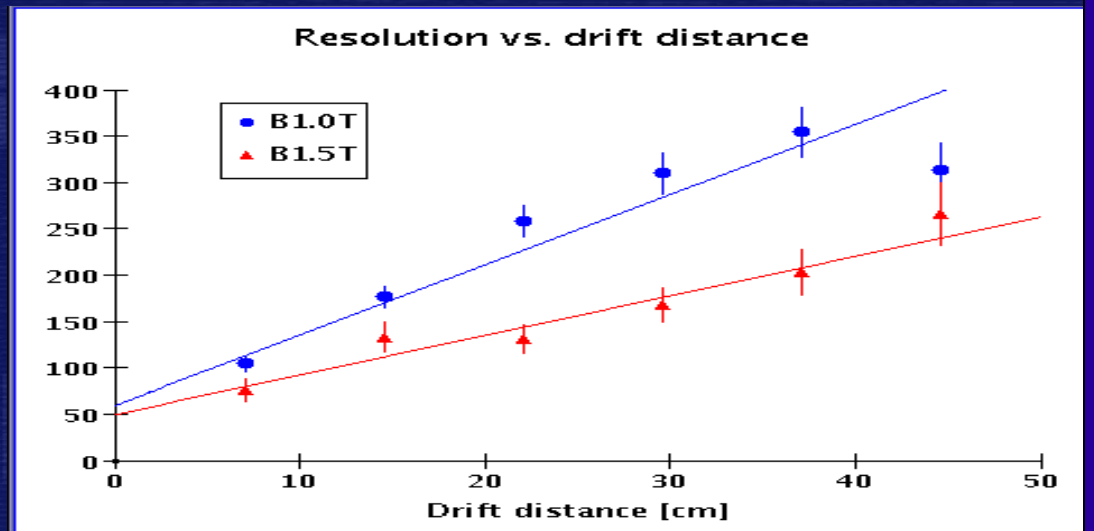
Integrated Large Area Trackers

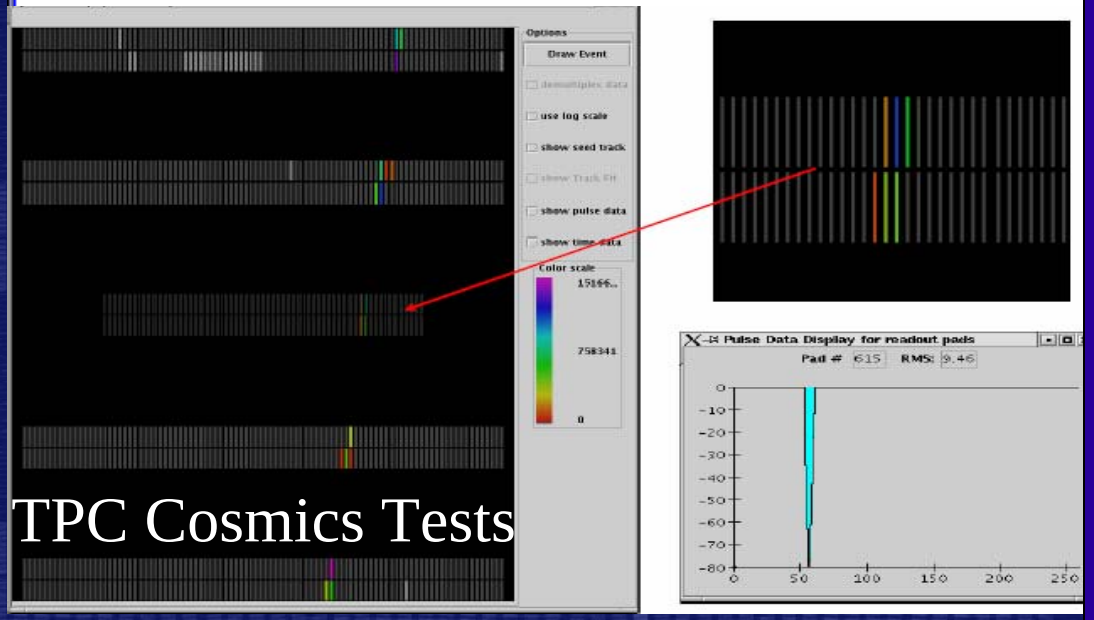
Innovations in large area 3D trackers needed to match challenge of boosting resolution by a factor of 10 with much reduced material budget

Improve 3D resolution adopting **MicroPattern Gaseous Detectors** and **high density readout** for optimal Track Pattern Recognition;

Achieve low mass endplates by developing **new structures** with embedded electrical, mechanical and thermal functionalities;

LBNL developing world-wide collaboration on TPC R&D (US, Canada, Europe, Japan)





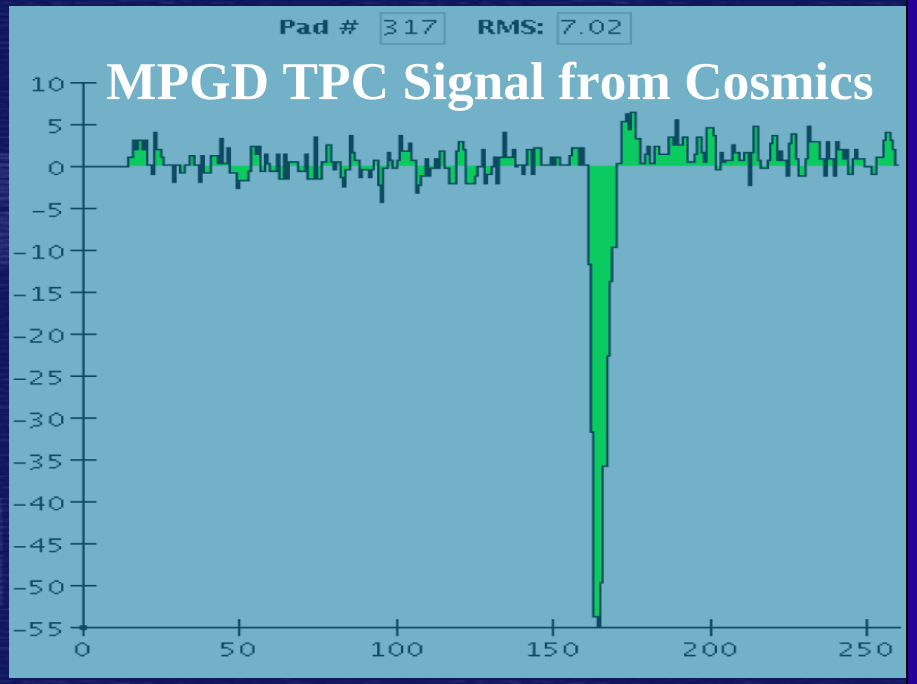
TPC Cosmics Tests

TPC with VLSI Readout R&D

Fully test new MPGD technology
Find optimal Gas & Operating conditions

Match readout technology to required granularity for optimal 3D resolution

Plan for FY05:
Build small scale **TPC prototype**,
Evaluate TPC **VLSI readout** from
Si pixel detectors with granularity matching primary ionisation spread using **ATLAS Pixel chip** and start conceptual **system design** addressing: time resolution, dynamic range, input protection, system noise reduction

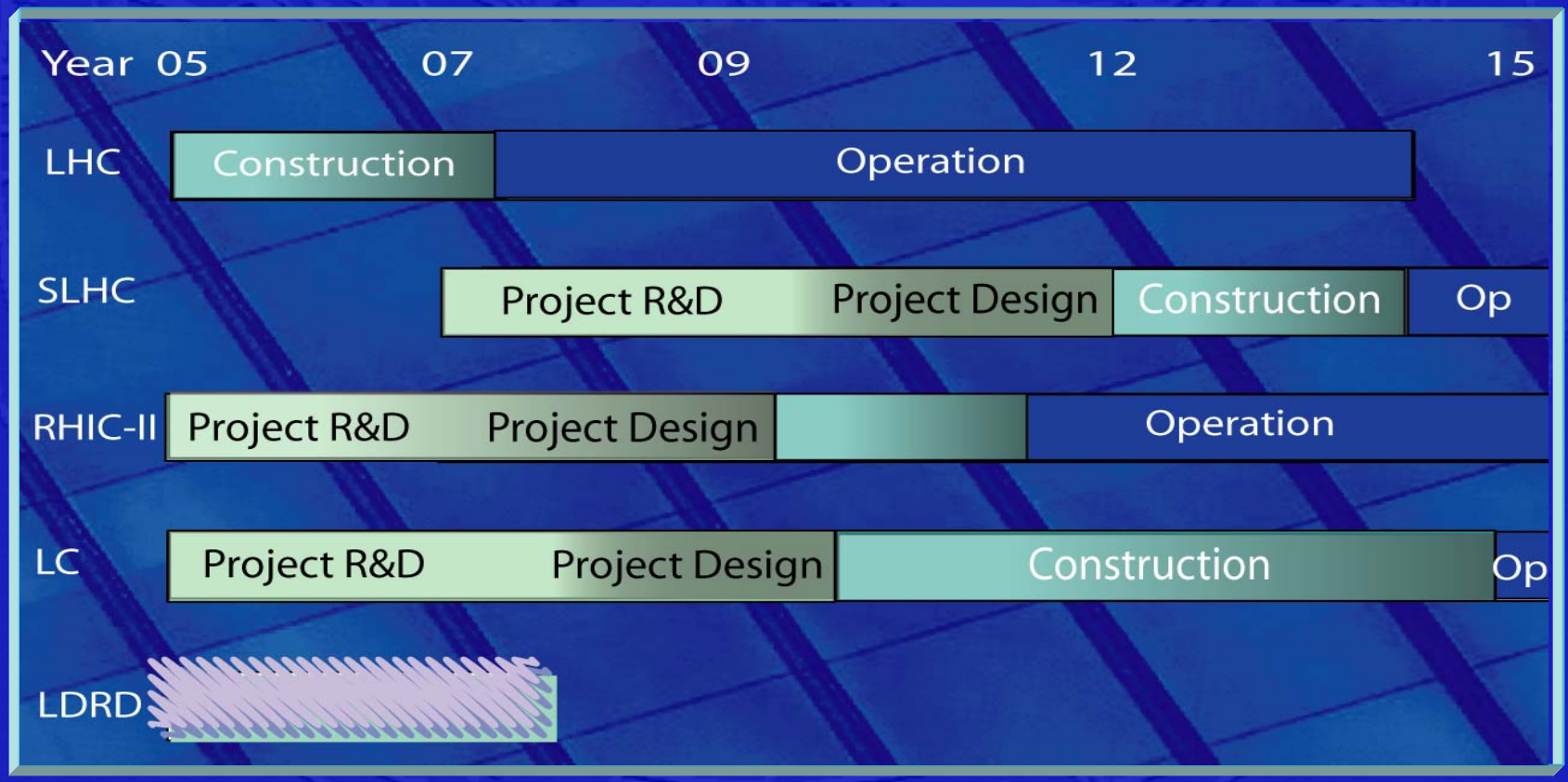


Track and δ Ray in TPC imaged with VLSI Readout

ILC Project and LDRD Timeline

ILC Project R&D effort represents **important part of US ILC program**

Perform R&D at forefront of **detector development** and **ensure contribution and leadership in design, planning and construction** of next generation of experiments at e^+e^- colliders in collaboration with University and Lab groups.



ILC and LDRD Project Plan

R&D Program based on synergy of activities with Engineering and Nuclear Science Divisions:

- share common technological basis
- develop common components and tests

Plan Study and R&D program open to Universities and other Labs:

Post-Docs and UCB GSRAs, shared with current programs, and UCB UGrads to train young physicists in time for future Experiments;

Collaboration with SLAC and University groups on development of common projects and soon to access LBNL ILC Lab facilities.

Project Staff and Faculty:
M. Battaglia (PI), G. Abrahms, Y. Kolomenski, M. Ronan

UCB GSRAs:
T. Orimoto

UCB UGrads
P. Charoenpong, B. Chickering, L. Ferrerosa, A. Gallardo, S. Ji, S. Liang, P. Penev, M. Tuchscher

Search for one PostDoc
+slot for one Graduate Student

Main Collaborating Institutions:
SLAC, UC Irvine, UC Davis, CEA Saclay, IReS Strasbourg, Purdue U., Victoria U.